PROTECTION OF PRIMARY FIXED-SATELLITE SERVICE FROM PROPOSED SECONDARY AIR-GROUND MOBILE SERVICES IN 14.0-14.5 GHZ

November 14, 2013

Overview

- Protection of GSO FSS from AMS
- Protection of NGSO FSS from AMS
- Policy and Licensing Issues

Note: This presentation is intended to be read in conjunction with the Satellite Industry Association's comments, reply comments and ex parte presentation submitted in GN Docket 13-114 and RM-11640.

Protection of FSS from Proposed Secondary AMS in 14.0-14.5 GHz

PROTECTION OF GSO FSS

Protection of GSO FSS (1)

- No more than 1% ΔT/T should be caused by all non-primary sources of interference into the primary FSS. (ITU-R Rec. S.1432)

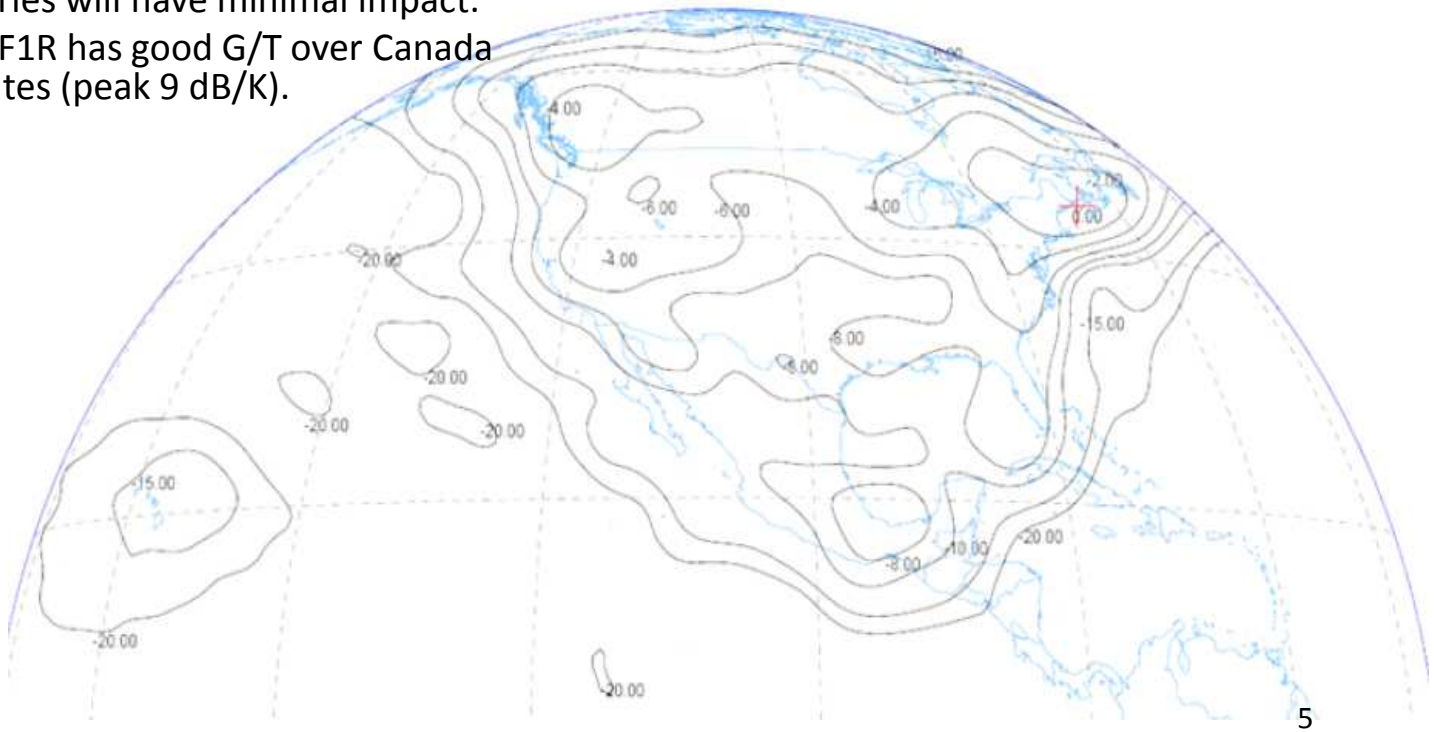
- Not appropriate to allocate the entire 1% allowance to the proposed secondary AMS when:
  - AMS will not be the only non-primary sources of interference in various parts of 14.0-14.5 GHz.
  - Possibility of future non-primary services in 14.0-14.5 GHz in the U.S. or in neighboring countries (including expansion of secondary AMS into Canada or Mexico).
  - Apportionment of the 1% is consistent with U.S. international positions.

- Any rules for the proposed secondary AMS must establish:
  - Enforceable aggregate interference limit of no more than 0.33% ΔT/T for GSO FSS.
  - Enforceable single-entry interference limits for AMS ground stations and aircraft terminals based on this aggregate interference limit.

Protection of GSO FSS (2)

- Other non-primary services in 14.0-14.5 GHz:
  - Federal Space Research Service in 14.0-14.2 GHz.
  - Federal Fixed and Mobile in 14.4-14.5 GHz.

- Possibility of future non-primary services, e.g. secondary AMS in Canada or Mexico
  - Qualcomm incorrect that secondary AMS in neighboring countries will have minimal impact.
  - For instance, Anik F1R has good G/T over Canada and the United States (peak 9 dB/K).



Contours show relative gain below peak in dB.

Average G/T for GSO FSS (1)

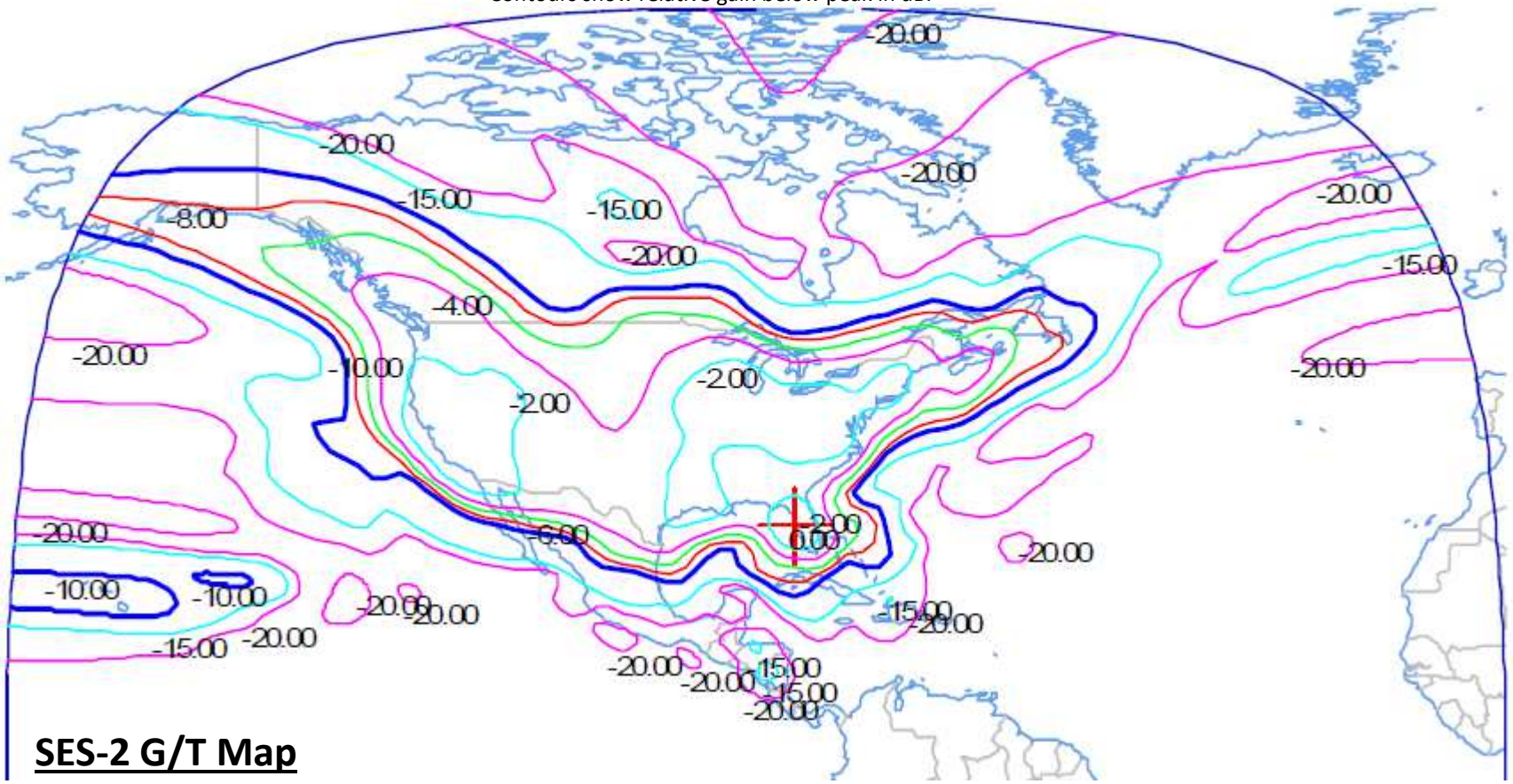
- The proposed secondary AMS must protect all primary FSS space stations to the ITU level – whether existing or future, U.S. or non-U.S.

- Thus, at the very least, protection levels must take into account the G/T of actual space station receivers authorized by the Commission

- A review of the G/T information submitted to the FCC as part of its space station authorization process indicates:
  - Qualcomm's proposed average G/T of 4 dB/K is lower than the G/T of authorized FSS satellites with full CONUS coverage
  - SIA's analysis indicates that an average of G/T of 6 dB/K must be used in order to protect already authorized full-CONUS satellites
  - Future satellites with even higher G/T over CONUS are possible, even under existing technology, and may require future adjustments to the protection levels

Average G/T for GSO FSS (2)

Contours show relative gain below peak in dB.



SES-2 G/T Map

Peak G/T = 7.99 dB/K

Edge of CONUS G/T = 4 dB/K

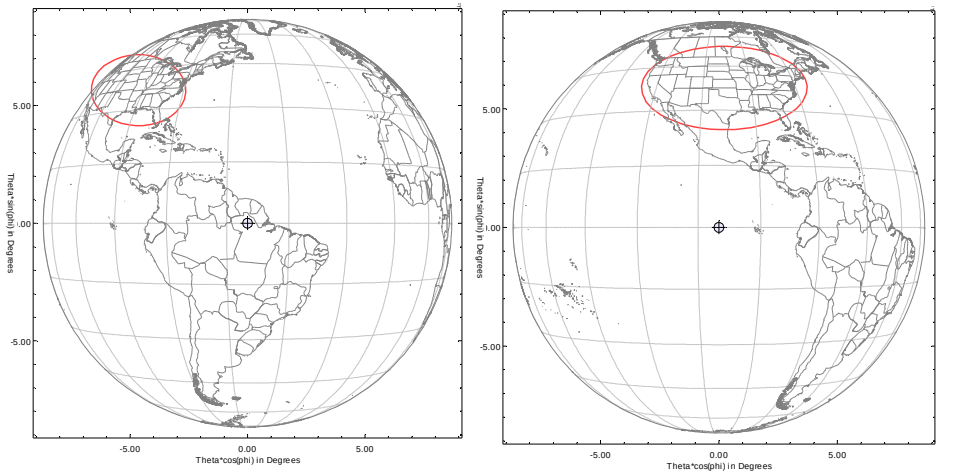
Average G/T = 6 dB/K

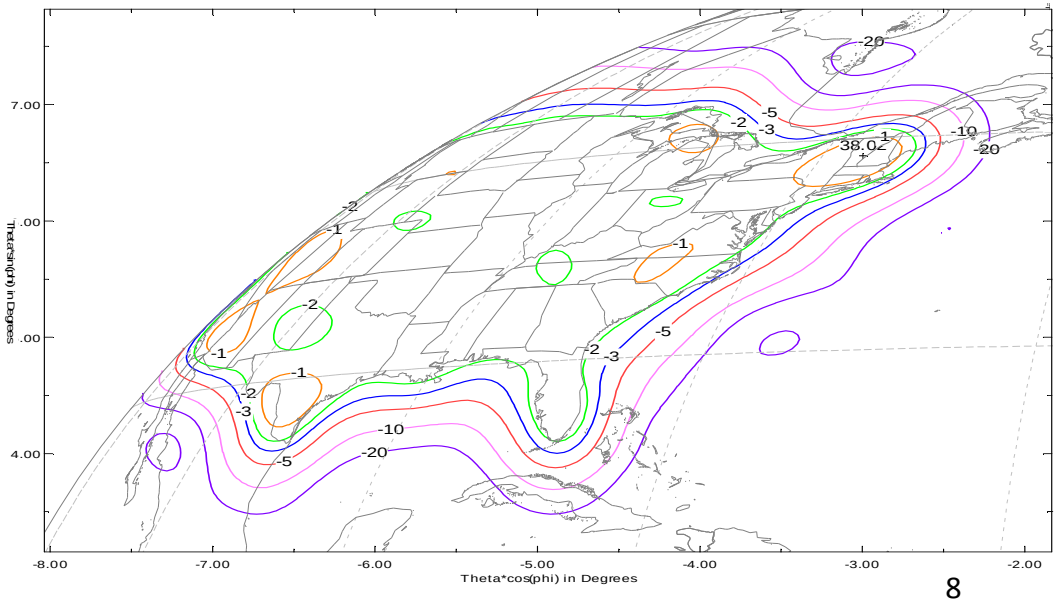
The G/T for SES-2 is greater than 4 dB/K for nearly all of CONUS

Average G/T for GSO FSS (3)

Not difficult to conceive of future satellites with higher G/T over CONUS (using existing technology)

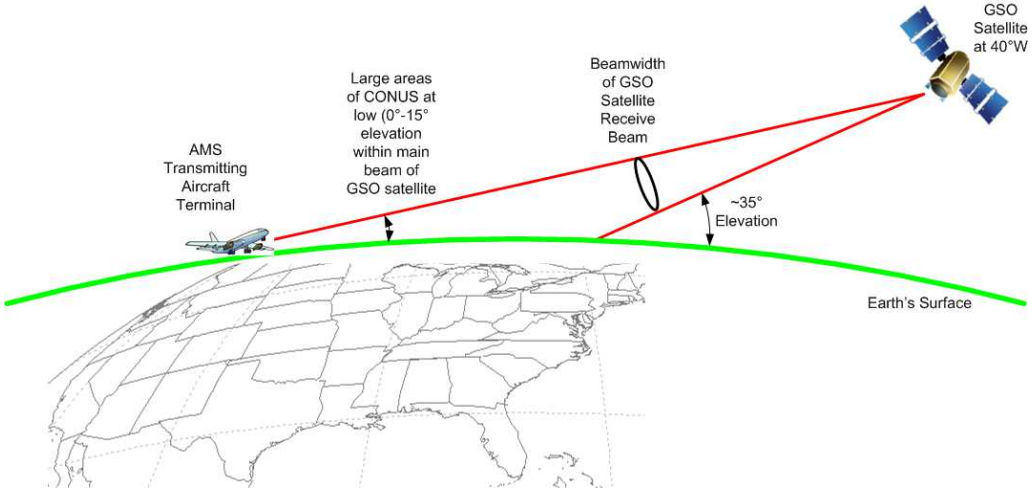
- For example, 55°W orbital position still “sees” essentially all of CONUS with a relatively narrow beam
- CONUS subtends solid angle of approx. 4°x3° from 55°W compared to 7°x3.5° from 100°W (i.e., half the solid cone angle)
- This implies a beam with less roll-off across CONUS
- Assume peak antenna gain is 38.02 dBi (within standard FSS receiver gains)
- Green contour at edge of CONUS is -2 dB, so average gain over CONUS is >36 dBi
- Assume Rx system noise temp is 500K
- Resulting average G/T is > +9 dB/K across CONUS



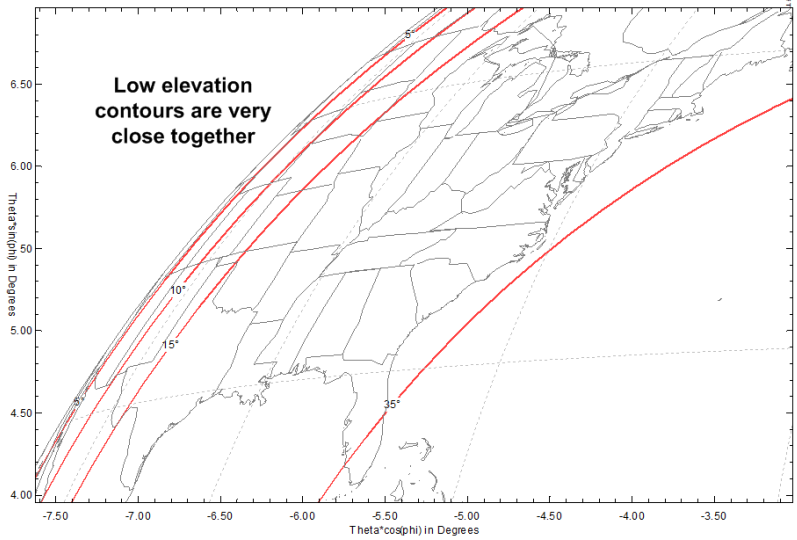


Aircraft Interference to Lower Elevation GSOs

- Qualcomm asserts that low elevation aircraft should not cause interference to a CONUS beam from 40°W because the GSO cannot provide service at such low elevation angles



SATELLITE VIEW FROM 40°W:



- But the low elevation directions are very close to the main service area of the GSO and so will inevitably have high satellite gain towards them
- Therefore must take account of low elevation interference

Qualcomm did not "consider satellites that are positioned at the far east … of CONUS"
Qualcomm did not "analyze the worst case scenarios"

Differences between SIA and Qualcomm Analysis of AMS Aircraft Interference into GSO FSS

SIA:

1. Assumed GSO satellite G/T averaged across CONUS is +6 dB/K.
2. Considered GSO at 40°W.
3. Ignores azimuth rejection of aircraft antenna and assumes the antenna is steerable in azimuth and pointed towards azimuth direction of GSO satellite.
4. Considered aircraft banking at 5°.

Qualcomm:

1. Assumed GSO satellite G/T averaged across CONUS is +2 dB/K.
2. Initially only considered GSO at 100°W and 140°W. Subsequently include new analysis also for 40°W.
3. Factors in azimuth rejection of aircraft antenna by assuming its beam is always pointing to an unknown and arbitrarily defined base station location. Therefore not possible to replicate Table 2 in Qualcomm Reply Comments.
4. Initially ignores aircraft banking in Table 3 of its Reply Comments, then proposes an 1.8 dB factor to take account of it.

Protection of FSS from Proposed Secondary AMS in 14.0-14.5 GHz

PROTECTION OF NGSO FSS

Protection of NGSO FSS

- The 1% ΔT/T criteria for protection of GSO FSS from all non-primary sources of interference applies equally to the protection of NGSO FSS systems

- The 6% ΔT/T criteria proposed by Qualcomm into NGSO FSS is wholly inappropriate
  - 6% ΔT/T is typically the threshold level of interference allowed from co-primary FSS operations without triggering coordination

- Just because an NGSO FSS system is not in operation today in the 14.0-14.5 GHz band does not justify a reduction in the protection criteria for primary FSS from non-primary services
  - Secondary services must protect both existing and future primary FSS deployments, including future primary NGSO FSS systems

Assumed G/T of NGSO FSS

- Qualcomm continues to assert that NGSO systems with G/T values higher than -7 dB/K would not be commercially viable.

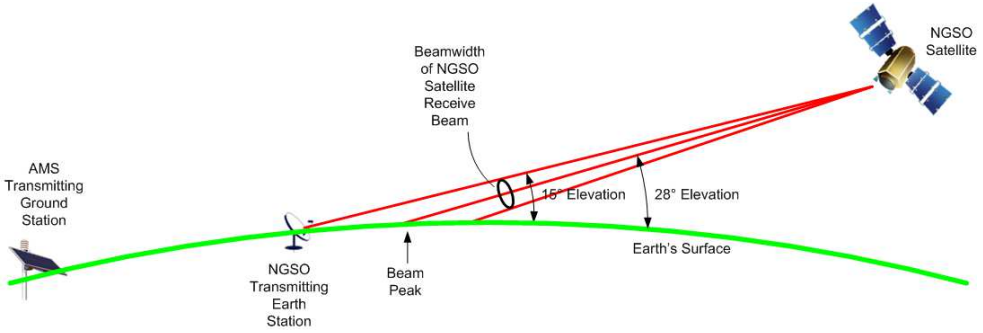
- SIA does not agree with this assumption. Future NGSO systems with higher G/T are viable and need not require more beams if they are targeting their steerable beams only towards customers. O3b is an example of this concept.

- Even at the lower assumed G/T of -7 dB/K for a future NGSO FSS system, both SIA's and Qualcomm's analysis show that interference levels exceed the 1% ΔT/T allowance for all non-primary interference sources.

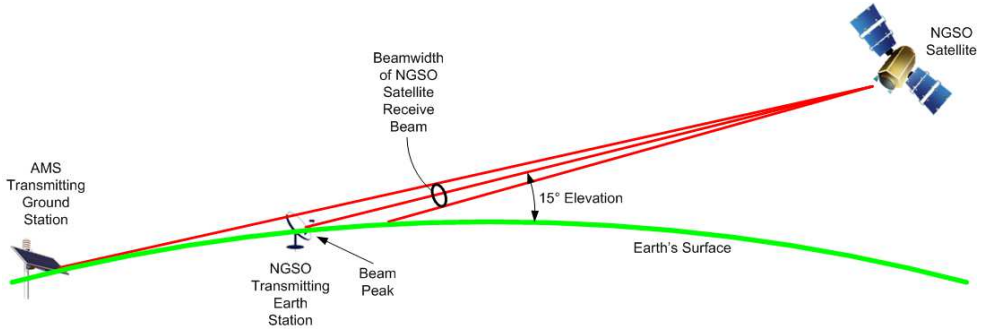
AMS Ground Stations Into NGSO FSS

- For the first time Qualcomm has analyzed (in its Reply Comments) interference from AMS ground stations into NGSO satellites arriving at low elevation angles (down to 1°)

- But Qualcomm still incorrectly assumes that NGSO satellite would not point its beam peak directly at its own low elevation (e.g., 15°) transmitting earth station. Instead, this is the scenario that Qualcomm uses →



- Qualcomm should analyze the realistic scenario where NGSO satellite beam peak is pointed towards 15 ° elevation (or lower) transmitting earth station as shown here → → → → → →



Qualcomm did not analyze the worst case scenario

Differences between SIA and Qualcomm Analysis of AMS GS Interference into NGSO (1)

SIA:

(assuming NGSO peak G/T = -7 dB/K)

1. For SIA Case B the NGSO satellite beam peak is pointed towards **15°** elevation earth location.
2. Resulting from 1. above the NGSO satellite receive beam roll-off towards the AMS GS is **-0.3 dB**.
3. Assumes **negligible** clear sky atmospheric attenuation under worst case interfering conditions at low elevation angles.
4. Resulting $\Delta T/T$ is **25.27%**.

Qualcomm:

(assuming NGSO peak G/T = -7 dB/K)

1. For Qualcomm analysis, assumes the NGSO satellite beam peak is pointed towards **28°** elevation earth location.
2. Resulting from 1. above the NGSO satellite receive beam roll-off towards the AMS GS is assumed to be **-4.64 dB**
3. Assumes additional **3 dB** atmospheric attenuation of the interfering signal under clear-sky conditions at 1° elevation *(not supported by any propagation model reference).*
4. Resulting $\Delta T/T$ is **4.6%**.

Differences between SIA and Qualcomm Analysis of AMS GS Interference into NGSO (2)

SIA:

(assuming NGSO peak G/T = +3 dB/K)

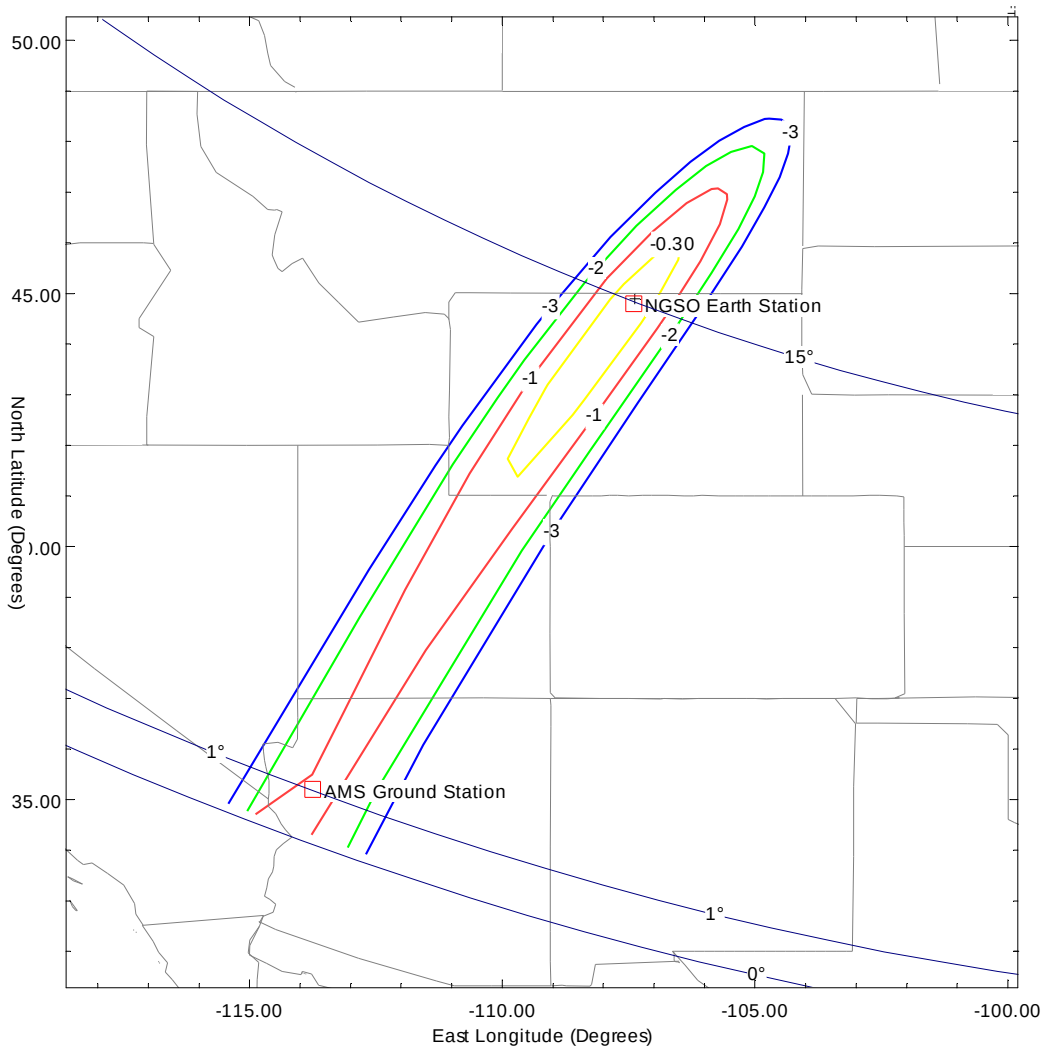
1. For SIA Case C, beam peak is pointed towards **15°** elevation earth location. (*Not at 1° elevation as stated by Qualcomm*)
2. Resulting from 1. above the NGSO satellite receive beam roll-off towards the AMS GS is **-1 dB**. (*see next chart to support this*)
3. Resulting $\Delta T/T$ is **215.05%**.

Qualcomm:

(assuming NGSO peak G/T = +3 dB/K)

1. For Qualcomm analysis involving NGSO peak G/T = +3 dB/K, in order to get the results it wants, Qualcomm assumes the NGSO system is incapable of providing service at less than **20°** elevation.
2. Resulting from 1. above the NGSO satellite receive beam roll-off towards the ATG GS is **-16 dB**.
3. Resulting $\Delta T/T$ is **3.3%**.

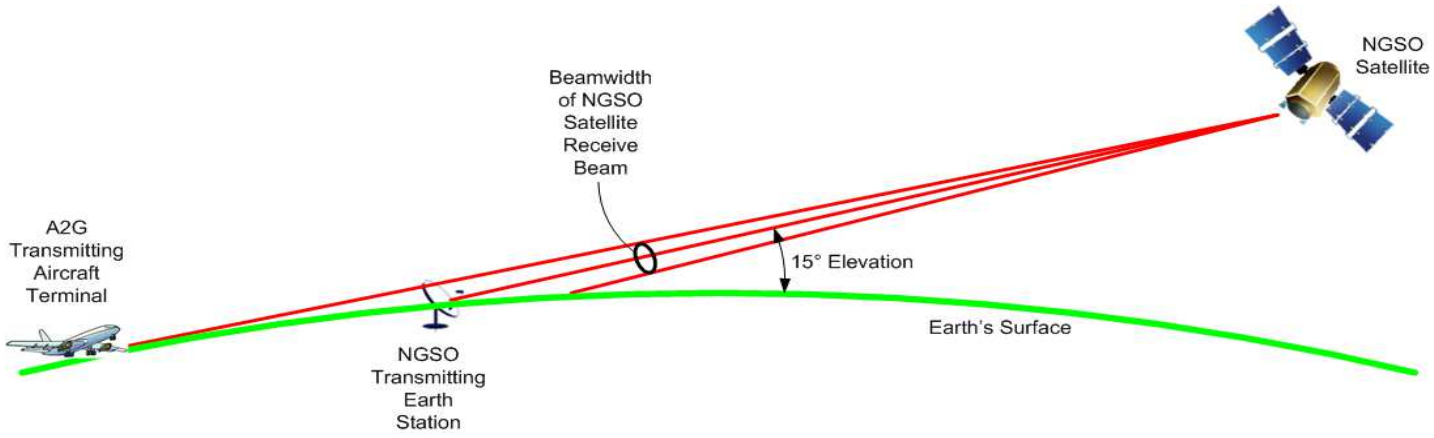
NGSO Satellite Beam with +3 dB/K G/T Pointed Towards 15° Elevation Location



- Beam plot shows a +30 dBi peak gain receive beam
- Equivalent to peak G/T = +3 dB/K assuming T = 500K
- Boresight (shown by a +) directed towards a transmitting earth station located on 15° elevation contour
- Results in -1 dB relative gain contour intersecting the 1° elevation contour

AMS Aircraft Terminal Interference to NGSO FSS

- In its Reply Comments Qualcomm was not able to refute the single-entry interference analysis presented by SIA in its Comments which shows that:
  - Reductions in the transmit power of each ATG aircraft terminal will be required to reduce the single-entry interference to high-gain future NGSO satellites to an acceptable level;
  - Significant reductions in the transmit power of the ATG aircraft terminals will be required to reduce the aggregate interference to future NGSO satellites to an acceptable level.
- Instead Qualcomm asserts that NGSO satellites will not need to operate at elevation angles below 20° based on the fact that there should always be an NGSO satellite available at a higher elevation angle. This argument is not valid and ignores the realities that may exist in the design and operation of an NGSO constellation, such as:
  - Need to retain satellite diversity options and not necessarily operate with the highest elevation satellite in order to, for example, comply with EPFD limits or share spectrum between NGSO systems
- Qualcomm also states that there could only be one rather than four aircraft per ATG cell pointing towards the same NGSO satellite using the same frequency. If this is in fact the case it still leaves a possible total of ten aircraft (from ten different ATG cells) causing an aggregation of interference into the same NGSO satellite. In this case the EIRP density of each aircraft terminal would need to be reduced by 5.2 dB, rather than the 11.2 dB proposed by SIA in its Comments.

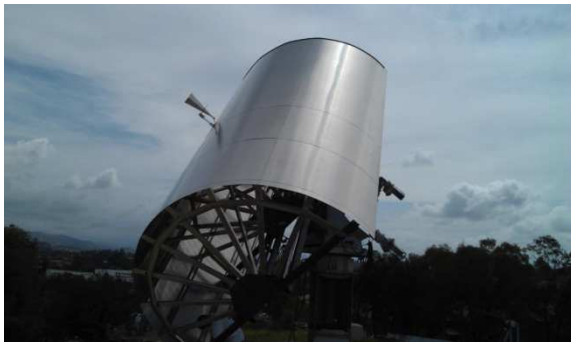


Protection of FSS from Proposed Secondary AMS in 14.0-14.5 GHz

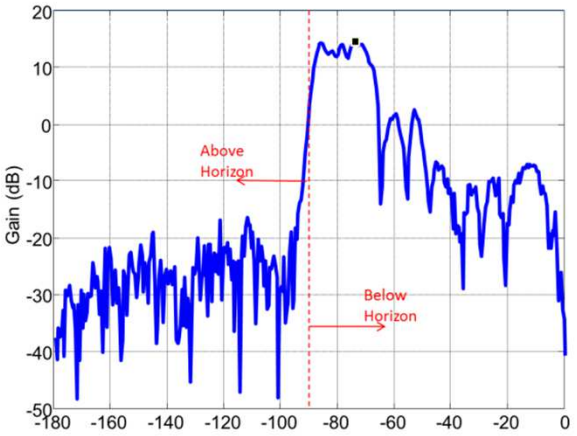
POLICY AND LICENSING ISSUES

AMS Aircraft Terminal Issues

- Qualcomm's aircraft antenna performance has evolved over time
  - Qualcomm's latest aircraft antenna pattern is being reviewed
  - We note that the latest prototype does not seem to be the blade antenna originally proposed by Qualcomm → → → → →
  - Variation in antenna designs underscores the need for verifiable antenna performance standards, not just aggregate limits



- Latest aircraft antenna design has exceedingly steep gain-roll off in elevation plane (> 5 dB per degree) → → → → → → → → → → →
  - Unclear if "Horizon" gain at 90 degrees elevation is actually the "Horizontal" gain, such that "Below Horizon" actually means "Below Horizontal" but which may still be above the actual horizon as viewed from aircraft
  - This is important because aircraft typically have a "nose up" attitude during flight
  - Increased risk of interference to FSS if:
    - Antenna performance is impacted by fuselage or other physical attributes of aircraft
    - Installation tolerances



Licensing and Compliance (1)

- If the FCC decides to proceed with the proposed secondary AMS, licensing of the AMS must be consistent with the interference protection rules and their enforceability
  - Number of licensees and their structure is important
  - Nationwide licenses vs. regional licenses vs. enforcement of aggregate limits
  - Secondary markets vs. enforcement of aggregate limits

- FCC must put in place viable procedures to verify compliance with all emission limits established for the secondary AMS, and must then enforce those limits.

- Enforceable limits that apply per aircraft terminal and per ground station terminal must be established to protect GSO and NGSO systems and must be adequately measured at equipment level before commissioning and operation of equipment.
  - Ground station and aircraft terminal emission limits must be made mandatory
  - Minimum antenna performance standards must be established and compliance must be verified

Licensing and Compliance (2)

- Aggregate limits (e.g., aggregate EIRP density towards the GSO) must also be established, but they cannot be reliably measured and must be derived from a combination of the following:
  a) Reliable equipment level performance for individual ATG terminals
  b) Expected AMS system parameters (e.g., numbers/locations of terminals, operating modes, constraints on system operation, etc)
  c) <u>Actual instantaneous, real-time operational parameters for the ATG system(s)</u>

- Item c) above must be sufficient to provide instantaneous, real-time, reliable calculation of the actual EIRP density towards all visible parts of the GSO, which must be made available to all FSS operators (e.g., AMS web-site)
  – Must use an agreed calculation methodology
  – Must include all the data used to derive the EIRP density levels
  – Records of the real-time parameters and calculated aggregate EIRP density levels must be kept

- AMS interference to NGSO FSS satellites must similarly be addressed using instantaneous, real-time data that demonstrates the interference mitigation method in use by the ATG operator and how this relates to the ephemeris data of the NGSO system.

Secondary Status of AMS

- As a secondary service, the AMS must protect and accept all interference from the FSS
  - Secondary AMS licensees will not be able to claim protection from FSS interference now or in the future.
  - SIA has shown repeatedly that interference into AMS will be more severe than Qualcomm anticipates
  - The impact on viability of AMS resulting from both the power reductions required to protect FSS and the interference from FSS must be assessed
  - If the Commission were to proceed with a secondary AMS, it must not be put in a position of being asked to change the rules to make the secondary AMS more viable in the future.

- AMS must not constrain irregular FSS operations
  - A number of routine but irregular FSS operations are conducted under Special Temporary Authorizations (STAs)
  - These include STAs for launch and early orbit phase, satellite relocation, use-prior-to-grant, and experimental operations
  - These irregular operations are essential for the continued innovation in and deployment of new FSS satellites and services
  - Constraining these irregular operations by requiring protection of the secondary AMS would unduly constrain the development of primary FSS in the 14.0-14.5 GHz band.

Consistency with FCC Patent Policy

- It has come to SIA's attention that Qualcomm has applied for a patent for "Overlaying an Air to Ground Communication System on Spectrum Assigned to Satellite Systems"
  - Application Number: 13/210,628
  - Application Date: August 16, 2011
  - Publication Number: US 2013/0044611
  - Publication Date: Feb. 21, 2013

- FCC Patent Policy (revised 1961)
  - In setting of technical standards, the FCC considers the impact of patent rights on the availability of equipment
  - Accordingly, the FCC should inquire into the status of Qualcomm's patent application and its proposed licensing practices as part of its public interest analysis of Qualcomm's proposal
  - There is a tension between setting technical rules for the protection of FSS that is based on Qualcomm's AMS architecture (which may be patented), and the desire of potential licensees for flexibility in how future AMS are implemented.

Some Examples of "Moving Targets" in Qualcomm's Proposal

- AMS Required C/(N+I)
  - In its initial July 7, 2011 filing, Qualcomm indicated that its ground-to-air and air-to-ground links require C/(N+I) of 4 dB.
  - Then in its July 31, 2012 filing that responded to an earlier SIA filing, it indicated that the 4 dB value was the C/(N+I) associated with the maximum/nominal data rate that it would like to transmit; however, it could operate with a reduced data rate with an associated C/(N+I) of -9 dB.

- AMS Data Capacity
  - In its initial July 7, 2011 filing, Qualcomm indicated that it wanted to operate with a bit rate efficiency of 1 bps/Hz, which for a 500 MHz spectrum would lead to a 500 Mbps data rate for each AMS beam.
  - However, in its July 31, 2012 filing, Qualcomm indicated that it could operate at a reduced capacity. Moreover, in its October 30, 2012 it indicated that it could accommodate a 30% reduction in capacity (due to interference into the ground-to-air link).

- Minimum Elevation Angle of the AMS ground-to-air beam
  - In its July 7, 2011 filing, Qualcomm indicates that the minimum elevation angle of its ground station beam will be 1°. However, in its September 11, 2012 filing, responding to an earlier SIA filing, it indicates (in a very poorly and confusing text) that the minimum elevation angle is 1.5°.

- Ground station off-Axis Antenna Gain Roll-off
  - In its July 7, 2011 filing, Qualcomm indicates that its ground station antenna will have roll-off of 37 dB (below the peak gain level of 37 dBi) in the direction of the geostationary arc.
  - Then in its July 31, 2012 filing it indicates that standard techniques can be used to suppress the off-axis gain by another 20 dB.

- AMS Aircraft Antenna Beam Gain Roll-off
  - In its initial July 7, 2011 filing, Qualcomm provides descriptively (in text) the off-axis gain performance of the AMS aircraft antenna.
  - Then in its September 11, 2012 filing, it uses the measured gain pattern of a prototype antenna to counter the arguments made by Telecomm Strategies included in SIA's August 31, 2012 filing.
  - On September 23, 2013, Qualcomm submits yet another set of antenna gain patterns.